ONTARIO AIR STANDARDS
FOR
CHLORINE

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Standards Development Branch
Ontario Ministry of the Environment

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Executive Summary

The Ontario Ministry of the Environment has identified the need to develop and/or update air quality standards for priority contaminants. The Ministry's Standards Plan, which was released in October, 1996 and revised in October, 1999, identified candidate substances for which current air standards will be reviewed over the next several years. Chlorine was identified as a priority compound for review based on its pattern of use in Ontario as well as the toxicological information that has been published subsequent to the development of the existing standard in 1984. A review of the scientific and technical information relevant to setting an ambient air quality standard for chlorine has previously been provided to stakeholders for their comments. A document providing the rationale for recommending an Ambient Air Quality Criteria (AAQC) and a half-hour Point of Impingement (POI) standard for chlorine has also been provided to stakeholders for their comments. This document summarizes comments from stakeholders on the proposed criteria and the responses provided by the Ministry. This document also provides the rationale for the decision on the air quality standards for chlorine.

Chlorine (CAS # 7782-50-5) is a greenish-yellow gas, liquid, or rhombic crystals. It has a suffocating odour with odour thresholds ranging from 0.021 - 3.4 ppm (61 - 9860 $\mu g/m^3$). It is used in the production of chlorinated solvents, chlorofluorocarbons, propylene oxide, pesticides, ethylene dichloride, and in special batteries that contain lithium or zinc. It is used as an intermediate for vinyl chloride monomer and polyvinyl chloride resin production. In the paper industry chlorine is used to bleach pulp. It is used in shrink-proofing wool. It is used in special batteries that contain lithium or zinc. Chlorine serves as a disinfectant or fungicide for applications such as water purification, cooling systems, and food processing, including meat, fish, vegetables, and fruit.

Chlorine is rapidly absorbed into the blood following exposure and is excreted from the body mainly through urination and defecation. It is considered moderately toxic and very irritating to humans when inhaled. Inhalation affects the respiratory system causing tracheal and bronchial changes, emphysema, chronic pulmonary edema, and congestion. Chlorine is also a strong irritant to the eyes and mucous membranes. The respiratory tract and the blood are the organ and tissue most affected by subchronic or chronic exposure to chlorine. Due to limited information concerning human and animal studies, the US Environmental Protection Agency (US EPA) has not drawn any conclusion on the carcinogenicity, developmental, or reproductive toxicity of chlorine.

Data obtained from the National Pollutant Release Inventory (NPRI) provided by Environment Canada indicates that emissions of chlorine to air across Canada declined significantly from 4153 tonnes in 1993 to 909.5 tonnes in 1997. Atmospheric emissions of chlorine in Ontario showed a similar decline. The most significant decreases in Ontario occurred between 1993 and 1994, when releases of chlorine declined from 1554 tonnes in 1993 to 181 tonnes in 1994. The release of chlorine in Ontario was reported to be 142 tonnes in 1997.

Neither Environment Canada nor the MOE routinely monitor ambient air for chlorine. The highest level recorded, during monitoring performed by the MOE in 1995, was under 200 $\mu g/m^3$ of chlorine (half-hour average) and was in the vicinity of a foundry in the Greater Toronto Area. In September 1991, near an aluminum plant in Windsor, the half-hour average concentrations were found to be around the detection limits of 0.28 - 0.44 $\mu g/m^3$.

In revising the air quality standards for Ontario, the Ministry of the Environment reviewed risk assessments and standards and guidelines developed by the US EPA, the States of California, New York, New Jersey, Michigan, the Commonwealth of Massachusetts, the World Health Organization, The Netherlands, the Swedish Institute of Environmental Medicine and the Canadian Federal Government. The States of California, Michigan, New Jersey, New York and the Commonwealth of Massachusetts have promulgated air quality guidelines or reference exposure levels for chlorine based on occupational exposure limits.

Current ambient air quality criteria from the U.S. state agencies are derived from occupational exposure limits. The different values are due to the varying uncertainty factors used in their derivation. The acute exposure limits of these agencies vary between 15 and 350 $\mu g/m^3$ and chronic exposure guidelines vary between 0.2 and 7.1 $\mu g/m^3$. The half-hour average emission guideline for The Netherlands is 5000 $\mu g/m^3$, which was established for permitting uses.

The State of California is proposing a revised acute Reference Exposure Level (REL) of 210 $\mu g/m^3$ based on irritation to humans as well as a chronic REL of 0.06 $\mu g/m^3$ based on respiratory effects of chlorine in animals. The Ministry considers that California's proposed RELs are derived from the most current information available and have addressed the health concerns of this compound. However, the Ministry considers that an in-depth evaluation of this information is appropriate only after the peer review process for these RELs are complete.

The Ministry of the Environment has reviewed and considered air quality guidelines and standards used by leading agencies world-wide. Of the criteria reviewed, the Ministry has evaluated and accepts the rationale which supports the current occupational exposure limit of 1,500 $\mu g/m^3$ (0.5 ppm) from the American Conference of Governmental Industrial Hygienists. After exposure averaging time conversion and the application of uncertainty factors, a 24-hour AAQC of 10 $\mu g/m^3$ has been derived.

In summary, based on the information reviewed from leading agencies, the assessment of toxicological information, and the stakeholder comments, the following Ambient Air Quality Criteria are set for chlorine:

- **10 µg/m^3 (24-hour average) based on health effects; and,**

- **230 µg/m^3 (10-minute average) based on odour nuisance.**

Based on supporting science and dispersion modelling, a half-hour POI standard of 30 µg/m^3 can be derived. However, considering the magnitude of the reduction from the previous standard of 300 µg/m^3 to this revised level of 30 µg/m^3, meeting this proposed POI standard immediately may not be possible.

In light of these potential concerns, the Ministry has determined an interim POI standard for chlorine:

- **300 µg/m^3 (half-hour average).**

The interim POI standard of 300 µg/m^3 has been determined for chlorine from the proposed range of 30 µg/m^3 to 300 µg/m^3, pending the outcome of consultation on a risk management framework, the introduction of new air dispersion models in Ontario, and proposed amendments to O. Reg. 346 to incorporate effects-based air standards with appropriate averaging times. The interim POI is already in place.

The Ministry is currently undergoing stakeholder consultation in the discussion paper "A Proposed Risk Management Framework for the Air Standard Setting Process in Ontario". The risk management framework addresses implementation timeframes for adopting final effects-based air standards (POIs and effects-based air standards with appropriate averaging times)as well as technology and economic issues linked to the introduction of new or revised air quality standards and the introduction of new dispersion models into Ontario's regulatory framework. Consultation is also underway in the discussion paper entitled: "Updating Ontario's Air Dispersion Models".

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1.0 Introduction

Ontario regulates air emissions in order to achieve and maintain air quality which is protective of human health and the environment. The *Environmental Protection Act* (Section 9) requires that all stationary sources that emit, or have the potential to emit, a contaminant obtain a Certificate of Approval which outlines the conditions under which the facility can operate.

The Ministry of the Environment uses a combination of regulated point of impingement (POI) standards and point of impingement guidelines in reviewing Certificates of Approval (MOEE, 1994a), each of which is derived by mathematical scaling, from an ambient air quality criterion (AAQC). Ambient Air Quality Criterion (AAQCs) represent human health or environmental effect-based values, and are normally set at a level not expected to cause adverse effects based on continuous exposure. As such, economic factors, such as technical feasibility and costs, are not explicitly considered when establishing AAQCs.

All sources are required to comply with the Point of Impingement standards that are included in the schedule of Regulation 346. The regulation (Section 5(3)) specifies that a source cannot, "cause or permit the concentration of a contaminant at a point of impingement to exceed the standard prescribed in Schedule 1". All sources are required to comply with the standards in Regulation 346 unless they are specifically exempt. The concentration of a contaminant at a POI may be calculated in accordance with the Appendix of Regulation 346 (Air Dispersion Models).

In addition to POI standards established under Regulation 346, the Ministry also has a large number of POI guidelines. These are used by the Ministry to assess general air quality, and the *likelihood* of causing adverse effect (MOEE, 1994a). Like the POI standards specified in Regulation 346, POI guidelines are used in reviewing applications for Certificates of Approval (Air), to approve new and modified emission sources. Once incorporated into a legal instrument such as a Certificate of Approval, POI guidelines are legally binding.

The Ontario Ministry of the Environment has identified the need to develop and/or update air guidelines/standards for priority toxic contaminants. The Ministry's Standards Plan, which was released in October, 1996 and revised in November, 1999 (MOEE, 1996; MOE, 1999a), identified 70 high priority substances for which current air standards will be reviewed, over the next several years. Factors used by the Ministry to determine which contaminants require priority include potential degree of exposure, volume of use, toxicity, Federal/Provincial commitments and sensitive sub-populations, including children.

In March 1998, following the 1996 initiative, the Ministry proposed a multi-step process for developing air quality standards (MOE, 1998). Initially, risk assessment and risk management information, relevant to establishing a standard for a particular compound, is documented (an Information Draft) and made available for stakeholder review through direct mail-out and posting

on the Environmental Registry. This provides stakeholders with the opportunity to critically review the information and provide any additional information they feel should be considered by the Ministry in setting an air quality standard for a particular compound. The Ministry considers comments received on the Information Draft and recommends proposed standards (a Rationale Document) and again solicits comments through direct mail-out and posting on the Environmental Registry for another public comment period. After assessing comments on the Rationale Document the Ministry finalizes its work by making a decision on the air quality standards by posting a Decision Notice onto the Environmental Registry.

Chlorine was identified as a priority for review based on its pattern of use in Ontario, and recent toxicological information that has been published since the previous standard was set in 1984. A review of scientific and technical information (MOE, 1999b) relevant to setting an ambient air quality standard for chlorine has previously been provided to stakeholders for their comments. A document (MOE, 2000) providing the rationale for recommending an Ambient Air Quality Criteria (AAQC) and a half-hour Point of Impingement (POI) standard for chlorine was also provided to stakeholders for their comments. This document summarizes comments from stakeholders on the proposed criteria and the responses provided by the Ministry. This document also provides the rationale for the decision on the air quality standards for chlorine.

2.0 General Information

2.1 Physical and Chemical Properties

The following list provides some general information on chlorine and its properties:

CAS #	7782-50-5
RTECS #	FO2100000
UN #	1017
Conversion Factors	1 ppm = 2.9 mg/m^3 @ 25 °C and 1 atm 1 mg/m^3 = 0.34 ppm @ 25 °C and 1 atm
Boiling Point	-34.05 °C at 760 mm Hg
Flash Point	Nonflammable
Henry's Law Constant	
Log K_{ow}	
Formula	Cl_2
Molecular Weight	70.90 g/mol
Vapour Density (air = 1)	3.21 mg/L at 0 °C and 1 atm
Vapour Pressure	5850 mm Hg @ 25 °C

Common Synonyms None

Chlorine is a greenish-yellow gas, liquid, or rhombic crystals (Lewis, 1992). It has a suffocating odour with odour detection thresholds range from 0.021 - 3.4 ppm (61 - 9860 $\mu g/m^3$) while the geometric mean for the odour detection thresholds is 0.08 ppm (232 $\mu g/m^3$) (AIHA, 1989).

2.2 Uses of Chlorine

Chlorine is used in the production of chlorinated solvents, chlorofluorocarbons, propylene oxide, pesticides and ethylene dichloride and as an intermediate for vinyl chloride monomer and polyvinyl chloride resin production. In the paper industry, chlorine is used to bleach pulp. It is used in shrink-proofing wool and in special batteries that contain lithium or zinc. Chlorine serves as a disinfectant or fungicide for applications such as water purification, cooling systems, and food processing, including meat, fish, vegetables, and fruit. Chlorine's disinfectant and fungicidal properties are also used in foot baths, dairy equipment, laundries, and dishwater (US EPA, 1994).

2.3 Sources and Levels

Sources

Chlorine is a naturally occurring element which, is also produced industrially (US EPA, 1994). Environment Canada's National Pollutant Release Inventory (NPRI) summarizes the emissions of chemicals in Canada based on information provided by reporting facilities. Chlorine is among the top 25 pollutants released to air (NPRI, 1995). Based on the summary reports of 1993 to 1997, total releases of chlorine in Canada have declined significantly, from 4153 tonnes in 1993 to 2034, 1244, 916 and 909.5 tonnes in 1994, 1995, 1996 and 1997, respectively (NPRI 1993; NPRI, 1994; NPRI, 1995, NPRI, 1996 & NPRI, 1997). The total releases in Ontario showed a similar pattern. In 1993, 1554 tonnes of chlorine were released, this amount decreased significantly to 181, 170, 144 and 142 tonnes in 1994, 1995, 1996 and 1997, respectively. The 1997 NPRI report listed 16 sources of atmospheric release of chlorine in Ontario, the vast majority of these releases were from forestry product industries.

From an analysis of recent applications for Certificates of Approval in Ontario, a sample of 26 facilities that emit chlorine were identified. These approvals were from emission sources from the forest product and mining industries, disinfectant uses and chemical plants. The median Ground Level Concentration (GLC) estimated by Regulation 346 dispersion modelling for all 26 sources was approximately 3 $\mu g/m^3$. The maximum and minimum were 301 and 0.00035 $\mu g/m^3$, respectively.

Ambient Air Concentrations

Environment Canada does not routinely monitor ambient air for chlorine. Monitoring undertaken in September 1991 found half-hour average concentrations to be around the detection limits of 0.28 - 0.44 $\mu g/m^3$, near an aluminum plant in Windsor (MOEE, 1994b). In 1995, the highest levels detected, of chlorine, were in the vicinity of a foundry in the Greater Toronto Area and were under 200 $\mu g/m^3$ (MOEE, 1997).

2.4 Environmental Fate

Vaporization of chlorine from water into the atmosphere is insignificant at neutral pH and low concentrations, but becomes significant at low pH values (i.e., pH 2) and high chlorine concentrations (~3,500 mg/L) (US EPA, 1994). Chlorine can play a role in the formation of photochemical oxidants (particularly nitric acid and sulphate), via the production of hydroxyl radicals, as shown in an industrialized area of Norway (Hov, 1984).

Chlorine may react with soil components to form chlorides which may be washed from the soil, depending on their water solubility (US EPA, 1994). Rapid hydrolysis of chlorine occurs in water, as the half-life of chlorine in natural waters is 0.005 seconds (US EPA, 1994). Chlorine does not bioaccumulate or bioconcentrate in biota (HSDB, 1994).

3.0 Toxicology of Chlorine

The following toxicological review of chlorine is primarily focussed on the inhalation route of exposure, as this is a primary pathway of human exposure to chlorine in air. Data on other exposure media are included where relevant, or where inhalation data are lacking.

Chlorine is rapidly absorbed into the blood following oral administration. It has been found that chlorine concentrations in rats peaked in two hours for fasted animals and in four hours for nonfasted animals (US EPA, 1994). Seventy-two hours after oral administration the concentration of chlorine was highest in the plasma, followed by bone marrow, kidney, testes, lung, skin, duodenum, spleen, liver, and carcass. The lowest concentration was found in the ileum. Similar results were observed 96 hours after a dose of 2.61 mg/kg was administered (US EPA, 1994). Once absorbed, free chlorine (Cl_2, OCl^-, or HOCl) is a powerful oxidizing agent that reacts readily with biological materials to produce a number of chlorinated organic compounds. Chlorine is excreted from the body mainly through urination and defecation. Rats given oral doses of chlorine excreted 36.4% in their urine and 14.8% in their faeces within 96 hours of dose administration. Chlorine compounds were not detected in expired air (US EPA, 1994).

3.1 Acute Toxicity

In general, chlorine is moderately toxic but very irritating to humans if inhaled. Inhalation of chlorine effects the respiratory system causing tracheal and bronchial changes, emphysema, chronic pulmonary edema, and congestion. It is also a strong irritant to the eyes and mucous membranes (Lewis, 1992). The extent of acute chlorine injury to humans is dependent, not only on the concentration and length of exposure, but also on the water content of the exposed tissue and the presence of a pre-existing cardiopulmonary disease. Clinical effects of different chlorine concentrations include mild mucous membrane irritation at 2.9-8.7 mg/m^3, which worsens to moderate irritation of the upper respiratory tract at concentrations of 14.5-43.5 mg/m^3. Immediate chest pain, vomiting, dyspnea, and cough occur at 87 mg/m^3, toxic pneumonitis and pulmonary edema at 116-174 mg/m^3, and death occurs after 30 minutes exposure to 1,247 mg/m^3 or after a few minutes at 2,900 mg/m^3 (US EPA, 1994).

A study on 29 volunteers of men and women, composed of smokers and non-smokers, were exposed to chlorine at 0, 0.5 or 2 ppm (0, 1.45 or 5.8 mg/m^3) for 4- or 8-hour periods (Anglen, 1981 as cited in OEHHA, 1998). Test subjects recorded their reactions upon entering the chamber at 15-, 30-, 60-, 90-, 120-, 180- and 240-minute intervals. Significant sensations of the urge to cough, itching and burning of the nose and eyes, and general discomfort were reported at or above 1 ppm (2.9 mg/m^3). A few subjects reported mild sensations of nausea, headache, dizziness, drowsiness or shortness of breath at the end of the 8-hour exposure period at 1 ppm (2.9 mg/m^3). There were significant changes in pulmonary function and increased subjective irritation at 1 ppm (2.9 mg/m^3), pulmonary functional changes were not observed at 0.5 ppm (1.45 mg/m^3) for the 8-hour exposure period and the subjective irritation was less severe. Medical examinations of the subjects indicated that there were some significant changes during the 8-hour exposure period at concentrations above 1 ppm (2.9 mg/m^3), such as increased mucous secretion from the nose and in the hypopharynx.

The ACGIH reviewed another study which reported that 8-hour exposures at 0.5 ppm (1.45 mg/m^3) produced irritation in workers. A study of 332 male workers in 25 chloralkali plants matched with 382 workers not exposed to chlorine was referenced in the ACGIH background documentation for chlorine. TWA exposure data were calculated for each worker on an 8-hour basis. Chlorine concentrations in the air were sampled every 2 months at different locations, within each of the plants participating in the study. All but 6 of the workers were reported to have exposures below 1 ppm, and 21 had TWAs above 0.52 ppm, the concentration of chlorine ranged from 0.006 to 1.42 ppm, with an average of 0.15 ppm. The average chlorine exposure was 10.9 years. Of 329 electrocardiograms from 332 workers, 9.4 % were abnormal compared with 8.5 % in the 382 controls, this was not considered a significant difference (ACGIH, 1991). The incidence of fatigue was greater in workers exposed to levels above 0.5 ppm, anxiety and dizziness showed a modest correlation with exposure level, however no neoplasia or serious permanent pulmonary damages were noted (ACGIH, 1991).

3.2 Subchronic/Chronic Toxicity - Inhalation

The respiratory tract and blood are the most affected by subchronic/chronic exposures to chlorine. In 55 workers, asthma, chronic bronchitis, tuberculosis, and emphysema were the result of chlorine exposure at 2.9 mg/m^3 for a minimum of ninety 8-hour work days. In another study of 15 male workers, exposed to 0.5 mg/m^3 for 8 hours/day, 5 days/week for 8.9 years resulted in decreased pulmonary function, such as decreased residual levels of maximal mid-expiratory flow rates and forced expired volume/functional vital capacity (FEV/FVC) (US EPA, 1994).

In a two-year lifetime exposure study, a LOAEL of 0.4 ppm (1.16 mg/m^3) for respiratory epithelial damages was observed in rats and mice (Wolf *et al.*, 1995 as cited in OEHHA,1997). Mice and male rats (70 animals per group) were exposed to chlorine concentrations of 0, 0.4, 1 and 2.5 ppm (0, 1.16, 2.9 or 7.25 mg/m^3) for 6 hours/day, 5 days/week. On the other hand female rats were exposed to 3 days/week, as a result of the observed higher sensitivity of the female rats. Significant histological changes in respiratory epithelia were observed in female rats exposed to concentrations above the 0.4 ppm (1.16 mg/m^3) level. Respiratory lesions studied included goblet cell hyperplasia, respiratory epithelium eosinophilic accumulation, glandular epithelium eosinophilic accumulation and olfactory epithelium eosinophilic accumulation.

Klonne *et al.* (1987 as cited in OEHHA,1997) exposed 32 male and female rhesus monkeys to chlorine at concentrations of 0, 0.1, 0.5 and 2.3 ppm (approximately 0, 0.3, 1.5 and 6.7 mg/m^3) for one year. The monkeys displayed statistical increases in tracheal and nasal lesions at the highest exposure, and a slight increase at the lower exposure levels.

3.3 Reproductive/Developmental Toxicity

Due to the limited information available from human and animal studies, the US Environmental Protection Agency (US EPA) has not drawn any conclusion on developmental or reproductive toxicity of chlorine (US EPA, 1994). In its derivation of its criterion for chlorine, the Massachusetts Department of Environmental Protection concluded that there was little evidence to suggest that chlorine acts as a developmental or reproductive toxicant (MDEP, 1995).

Female Sprague-Dawley rats given chlorine concentrations of 0, 1.0, 10, or 100 mg/L in their drinking water for 2.5 months prior to conception and throughout gestation, were killed on gestation day 20, and the fetuses were examined. Resorptions were not increased at any concentration. However, soft tissue defects were observed in fetuses in the 100 mg/L group, including improper orientation of the heart and adrenal agenesis, and a slightly increased incidence of skeletal variants, such as incompletely ossified or missing sternebrae or rudimentary ribs (US EPA, 1994). In other studies, pregnant mice were administered with chlorine in drinking water as 29-38 mg/m^3 of sodium hypochlorite and hydrochloric acid (to maintain water pH of 2.5). Results were negative for reproductive and teratogenic effects when administered as

described above, or when given in heavily chlorinated municipal drinking water (US EPA, 1994). B6C3F1 mice that where given 1.6 and 4.0 mg/kg/day of chlorine as dissociated hypochlorite (OCl^-) had sperm head abnormalities, however no sperm abnormalities were observed at 8.0 mg/kg or when given as hypochlorite (HOCl) (US EPA, 1994).

3.4 Genotoxicity

There are equivocal results on the mutagenicity of chlorine. It was mutagenic in *Salmonella typhimurium* strains TA1530 and TA100, without metabolic activation, produced chromosome aberrations in human lymphocytes and other mammalian cells at 1798 mg/m^3, interacted with DNA in E. Coli polA test (as sodium hypochlorite), and was negative for the induction of erythrocyte micronuclei or chromosome aberrations of bone marrow cells of Swiss CD-1 mice (up to 8 mg/kg/day of NaOCl) for up to 5 days (US EPA, 1994).

3.5 Carcinogenicity

Due to limited data, the US EPA has not drawn any conclusion on the carcinogenicity of chlorine (US EPA, 1994). In a study of F344/N male and female rats, and $B6C3F_1$ male and female mice (50/sex/group), received 0, 70, 140, or 275 ppm (0, 203, 406 or 798 mg/m^3) chlorine in their drinking water for 2 years. The results from this study showed that the female rats had a slight increase in the incidence of mononuclear cell leukemia, but it was not clearly dose-related (control, 8/50; low dose, 7/50; mid-dose, 19/51; high-dose, 16/50), however it was considered by the US National Toxicology Program (NTP) to be "equivocal evidence of carcinogenic activity" in male rats or male and female mice at the doses tested (NTP, 1992). In another study, chlorine administered as NaOCl to rats in drinking water at levels up to 1000 mg/L for males and 200 mg/L for females showed no signs of carcinogenicity. (NTP, 1992). The NTP noted that some epidemiologic studies have shown an association between the consumption of chlorinated drinking water and an increased risk for the development of cancer, primarily of the urinary tract. However, the role of molecular chlorine versus chlorination by-products, such as chloroform, is unclear (NTP, 1992).

3.6 Environmental Effects

Chlorine, although essential to plant growth, is also phytotoxic. Chlorine is absorbed by and accumulates in plant leaves. Foliar injury is dependent upon chlorine concentration and species as well as exposure duration. The most sensitive species found in the available literature are radishes and alfalfa which demonstrated a toxicity threshold for leaf damage of 0.29 mg/m^3 (0.1 ppm) after a 2-hour exposure to chlorine (Brennan et al, 1965). Acute toxicity to lower plants is characterized by defoliation with no-leaf symptoms and, in higher plant forms, by spotting of the leaves (at 1.5 mg/m^3) and interveinal injury at 150 to 300 mg/m^3 (US EPA, 1994). Crops (bean, radish, and rose) began to show foliar injury after exposure to 3.8 mg/m^3 chlorine for a half hour

(Zimmerman, 1955). A study conducted on the Granary weevil showed 30% survival after exposure to 1% Cl_2 gas for 10 minutes and 38% survival after exposure to 20% Cl_2 gas for 2 minutes (Leukel, 1940).

Chlorine has high acute toxicity to aquatic organisms as many toxicity values are less than 1 mg/L. Ninety-six-hour LC_{50} values for aquatic organisms range from 0.017 mg/L for the water flea, *Daphnia pulex* (Hall, 1981) to 0.1 mg/L for fathead minnow (*Pimephales promelas*) (Environment Canada, 1984).

4.0 Existing Air Quality Regulations

4.1 Overview

The documentation for ten agencies, including the United States Federal Government, the States of California, New York, New Jersey and Michigan, the Commonwealth of Massachusetts, the World Health Organization, The Netherlands, the Swedish Institute of Environmental Medicine and the Canadian Federal Government, was reviewed for the existence and the basis of their air quality criteria for chlorine. A brief summary of this review is presented in Table 1, and agency-specific summaries of information concerning air quality guidelines for toluene are presented in Section 10.0, the Appendix of this report.

In reviewing the air quality guidelines and exposure limits presented in Table 1, it should be noted that the MOE normally uses a factor of **15** to convert from criteria based on annual average concentrations to half-hour POI standards, and a factor of **3** to convert from criteria based on 24-hour average concentrations. These factors are derived from empirical measurements and are selected to ensure that if the short-term limit is met, air quality standards based on longer-term exposures will not be exceeded (MOE, 1987; MOEE, 1994b). However, depending on the health end-point being considered, other conversion factors may also be employed.

Of those reviewed, 5 agencies have air guidelines (the States of California, New York, New Jersey and Michigan, the Commonwealth of Massachusetts). These agencies have developed their criteria from workplace exposure limits. The acute exposure limits vary between 15 and 350 $\mu g/m^3$, and chronic exposure guidelines vary between 0.2 and 7.1 $\mu g/m^3$. The Netherlands have an emission standard of 5,000 $\mu g/m^3$. The State of California is proposing an acute reference exposure level of 210 $\mu g/m^3$ (OEHHA, 1998) and has revised a chronic level of 0.2 $\mu g/m^3$ level (OEHHA, 2000). These criteria are derived from human and animal studies. A risk assessment for chlorine is under review by the US EPA.

Table 1. Summary of Existing Air Quality Guidelines[1] for Chlorine

Agency	Guideline Value	Basis of Guideline	Date[2]	Comments
US EPA	No ambient air exposure limits are available. RfC: under review.		 1997	 No air guideline promulgated.
California	Chronic REL, 0.2 $\mu g/m^3$ (annual average) Acute REL: 23 $\mu g/m^3$ (1-hour average) Proposed: acute REL, 210 $\mu g/m^3$ (1-hour average)	Respiratory effects Respiratory irritations Irritant effects.	2000 1993 1998	Chlorine appears on the Toxic Air Contaminants Identification List.
Massachusetts	TEL (Threshold Effects Exposure Limits): 3.95 $\mu g/m^3$ (24-hour average). AAL (Allowable Ambient Limit): 3.95 $\mu g/m^3$ (annual average).	TLV-TWA from ACGIH. TLV-TWA from ACGIH.	1995 1995	Adjusted to allow for exposures via other media. Adjusted to allow for exposures via other media.
Michigan	ITSL (Initial Threshold Screening Level): 15 $\mu g/m^3$ (8-hour average).	TLV-TWA from ACGIH.	1997	Permitting standard, i.e., the Predicted Ambient Impact of a toxic from any facility cannot exceed its screening level.
New Jersey	RfC (Reference Concentration for Inhalation): 7.1 $\mu g/m^3$ (annual average)	Chronic REL from California	1997	Adopted California's REL. Used for permitting.
New York State	SGC (Short-term Guideline Concentration): 350 $\mu g/m^3$ (1-hour average). AGC (Annual Guideline Concentration): 3.5 $\mu g/m^3$.	REL-TWA from NIOSH. REL-TWA from NIOSH.	1991 1991	Used for permitting. Used for permitting.
WHO	None.			
Netherlands	5,000 $\mu g/m^3$ (half-hour average).	Emission standard.	1992	Used for permitting.
Sweden	None.			
CEPA	None.			
Ontario	(Note: see comments for replaced air quality standards) POI Standard: 300 $\mu g/m^3$ (half-hour). AAQC: 150 $\mu g/m^3$ (24-hour).	Health effects. Health and vegetation effects.	1984	Previous Ontario air quality standards which have been replaced with the current air quality standards.

1. Guidelines in this table can refer to: guidelines, risk-specific concentrations based on cancer potencies, and non-cancer-based reference concentrations.
2. Date here refers to when the health-based guideline background report or the original legislative initiative was issued. The sources were the respective agency documents. For the US EPA, date refers to when the latest review of the RfC was conducted, if applicable, or the date the IRIS database was accessed, in the case where no RfC has been developed.

4.2 Evaluation of Existing Criteria

Due to lack of data, no agency has performed a carcinogenicity risk assessment, therefore the cancer end-point has not been considered a basis for their criteria.

The States of California, Michigan, New Jersey and New York, and the Commonwealth of Massachusetts have based their criteria, or reference exposure levels for chlorine on occupational exposure limits. Specifically, the criteria of the states of Massachusetts, Michigan and California are based on the American Conference of Governmental Industrial Hygienists' (ACGIH) limit, and that of the State of New York standard is based on the National Institute for Occupational Safety and Health's (NIOSH) limit. New Jersey has adopted the chronic reference exposure level of the State of California.

The ACGIH developed its occupational exposure limits based on health studies on workers. It was reported that exposures of 1 ppm of chlorine for 8 hours produced statistically significant changes in pulmonary function and increased subjective irritation. At lower concentrations, chlorine did not affect the lower respiratory tract but may irritate the eyes, nose and throat (ACGIH, 1991, ACGIH, 1999). The ACGIH recommended a threshold limit value-time weighted average (TLV-TWA) of 0.5 ppm (1.5 mg/m^3) for chlorine to prevent eye and mucous membrane irritation, based on studies examining chlorine-induced irritations experienced by human subjects (ACGIH, 1991). NIOSH also recommended an exposure limit (REL) of 0.5 ppm (1.5 mg/m^3), which is based on the consideration of eye and respiratory irritations (NIOSH, 1988).

The variation in the values of the air quality criteria of these agencies reflect slightly different science/policy considerations in the application of uncertainty factors, particularly when deriving an ambient level criterion from a workplace exposure limit. New York State applied an uncertainty factor of 4.2 to the REL of 1,500 $\mu g/m^3$ of the NIOSH to come up with its short-term guideline concentration (SGC) value of 350 $\mu g/m^3$. New York State also applied a factor of 420 (4.2 for exposure derivation and 100 for a "moderate toxicity" for chlorine) to the REL of NIOSH to obtain its annual guideline concentration (AGC) of 3.5 $\mu g/m^3$.

The Massachusetts Department of Environmental Protection (MDEP) obtained its criterion (threshold effects exposure limit, TEL) of 3.95 $\mu g/m^3$ by dividing the occupational exposure limit of 1,500 $\mu g/m^3$ of the ACGIH by a total uncertainty factor of 367.5 calculated as 4.2 for extrapolation from a work week to continuous exposure, 1.75 to account for difference in sensitivity between adults and children, 10 to account for high risk groups and 5 for multimedia exposure (MDEP, 1994).

The State of Michigan applied an uncertainty factor of 100 to the TLV-TWA (1,500 $\mu g/m^3$) of the ACGIH to obtain its initial threshold screening level (ITSL) of 15 $\mu g/m^3$. In its derivation,

the uncertainty factor included: the conversion of discontinuous to environmental exposures with a factor of 4.2; a worker may spend half of his/her life span in the work environment (30 over 70 years); and 10 for sensitive individuals.

In deriving its current chronic exposure level, the State of California modified the previous TLV-TWA of 2,900 $\mu g/m^3$ (1 ppm; 1969-1988) from the ACGIH using an uncertainty factor of 420 (4.2 to extrapolate from a 40 hour work week, 10 for extrapolating from workers to the general population, and 10 to go from a LOEL to a NOEL, as adverse effects are reported at this level).

Recently, the Office of Environmental Health Hazard Assessments of the California EPA has established a revised chronic inhalation reference exposure level (REL) of 0.2 $\mu g/m^3$, based on a well-designed animal inhalation study (see Appendix 10.2). In this two-year lifetime exposure study, a LOAEL of 0.4 ppm (1.16 mg/m^3) for respiratory epithelial damages was observed in rats and mice (Wolf *et al.*, 1995, as cited in OEHHA,2000). It was found that a parallel analysis, using the benchmark (BM) dose analysis, performed on data for glandular epithelium eosinophilic accumulation in female rats resulted in a BMC_{05} (benchmark concentration) of 0.14 ppm (0.4 mg/m^3), which was 3-fold lower than the identified LOAEL. A BMC_{05} or a BMC_{10} is considered to be similar to a NOAEL in estimating a concentration associated with a low level risk. The BMC_{05} of 0.14 ppm was corrected for continuous exposure and extrathoracic respiratory effects. Uncertainty factors of 3 and 10 for inter- and intra-species variabilities, respectively, were then applied to obtain a REL of 0.08 ppb or 0.2 $\mu g/m^3$.

California identifies the strength of the REL since it is based on a well conducted inhalation study using multiple doses. Given that rhesus monkeys also exhibited similar adverse effects as rodents, California suggests that rodents are an appropriate model for humans. It also recognised that no NOAEL has been observed, there are limited reproductive data on chlorine and inadequate data on human exposure.

California is also proposing to revise its present acute reference exposure level of 23 $\mu g/m^3$ to 210 $\mu g/m^3$ (OEHHA, 1998). The present value was adopted from ACLs (ambient concentration limits) derived by Lewis and Alexeeff (CAPCOA, 1993). The proposed value is derived from the study of Anglen (1981 as cited in OEHHA, 1998). In this study where human volunteers were exposed, a NOEL of 1 ppm (2,900 $\mu g/m^3$) was observed for a half-hour exposure. This value was extrapolated to a one-hour exposure of 2,100 $\mu g/m^3$. An uncertainty factor of 10 was then applied for extrapolation to sensitive populations to obtain an acute REL of 210 $\mu g/m^3$. However, in the study of Anglen (1981), it was reported that exposure at 1 ppm (2,900 $\mu g/m^3$) for 1 hour produced consistent, and statistically significant increase in throat irritation and a significant decrease in the group's mean forced expiratory volume (FEV_1; possible changes in pulmonary function). Exposure to 0.5 ppm (1,500 $\mu g/m^3$) for 4 hours did not consistently induce

throat irritation and urge to cough. Therefore, this may cast doubts in the determination of an appropriate NOAEL by the OEHHA (see section 11.2).

5.0 Responses of Stakeholders to the Information Draft

In January 1999, the Ministry posted information draft documents for eighteen chemicals, including chlorine, for air quality standards development under the Standards Plan (MOEE, 1996; MOE 1999). The Ministry requested input regarding: the completeness of relevant inhalation toxicological information examined by the Ministry; the rationale of the agencies that the Ministry has considered appropriate for the development of air quality standards; and any technical or economic impacts that may be anticipated as a consequence of the potential revision(s) of the air quality standard.

During the consultation period the Ministry received one submission from a stakeholder regarding the draft document for chlorine. A rubber manufacturer indicated that they were in the process of reducing emissions of chlorine, therefore a new standard between 30 $\mu g/m^3$ and 150 $\mu g/m^3$ should not present any difficulties.

6.0 Responses of Stakeholders to the Rationale Document

On February 21, 2000, the Ministry posted to the Environmental Registry a document titled "Rationale for the Development of Ontario Air Quality Standards for Chlorine" and requested public comments over a period of 90 days. Four submissions were received and the concerns of stakeholders are summarized below.

Comments Specific to Chlorine:

No comments were received that were specific to the proposed standards for chlorine.

Comments of a General Nature:

Four submissions included general comments applicable to any of the proposed air standards. The comments are summarized below with the Ministry's response.

Comment: The proposed standards are not based on the latest scientific information.

Response: The Ministry considers the most credible science when revising existing air standards or developing new air standards. During the Information Draft stage of the air standard setting process, stakeholders are encouraged to provide any additional scientific information that they

feel the Ministry should consider when developing or revising air standards. In some instances, new and credible scientific information has been published following the posting of the Rationale Document to the Environmental Registry. In these instances, the Ministry assesses the new information in detail before making a decision on the proposed air standard.

Comment: The proposed standards do not integrate socio-economic considerations.

Response: The proposed standards are set at effects-based levels. Socio-economic considerations are taken into account during the implementation phase (risk management) of the standards setting process. The Ministry is consulting with stakeholders on a risk management framework to ensure fair and equitable implementation of new air standards.

Comment: It is not clear how stakeholder input was incorporated into the decision-making process.

Response: The Ministry accepts this comment from stakeholders. We are improving our air standards documentation to better explain how stakeholder comments were considered in the decision making process. A summary of comments and responses is included in this document.

Comment: The proposed standards, the introduction of new dispersion models, and the assessment of compliance are all linked.

Response: The Ministry acknowledges that these issues are all linked and will be having joint consultation sessions with stakeholders on a risk management framework and on the introduction of new dispersion models for use in Ontario.

Comment: An appropriate phase-in period is required for both the proposed standards and the introduction of new dispersion models.

Response: The Ministry agrees that an appropriate phase-in period is important. The Ministry is consulting with stakeholders on an appropriate phase-in period for new standards and on the introduction of new dispersion models for use in Ontario.

Comment: There is concern about the ability to meet the proposed standards and that the potential costs to comply will make Ontario industries uncompetitive.

Response: The Ministry is consulting with stakeholders to address these risk management issues. A risk management framework will help companies determine their options to achieve compliance.

Comment: The Ministry of the Environment is adopting exposure guidelines used in other jurisdictions as regulatory limits in Ontario.

Response: The Ministry reviews the science supporting the exposure guidelines of other jurisdictions. If Ministry experts concur with the scientific assessment of other jurisdictions, the published exposure guideline is used as a basis for proposing a regulatory limit in Ontario.

Comment: The use of 30 minute screening limits (i.e. 30 minute Point of Impingement) may be an unrealistic estimate of causing an adverse effect.

Response: Use of the proposed new dispersion models would allow for a more representative assessment of environmental and health impacts by using the most appropriate averaging time for exposure. The effects of a contaminant could then be assessed using modelled exposure concentrations over the most appropriate averaging time for that contaminant. For example, the effects-based averaging time for health-based air standards is 24 hours (or daily) exposure. These concepts are currently out for consultation in the Discussion Paper entitled: "Updating Ontario's Air Dispersion Models".

Comment: The proposed use of US EPA Reference Concentrations (RfC) as 24-hour criteria yields standards 5 times more stringent than necessary.

Response: The Reference Concentration is defined by the US EPA as "...an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious non-cancer effects during a lifetime". The RfC is calculated on the basis of a daily exposure over a 70 year lifetime. Jurisdictions apply Reference Concentrations in a manner consistent with their policies and regulations. Ontario considers the 24-hour AAQC a daily limit for long-term exposures. This approach is also used by some other jurisdictions in North America.

Comment: The use of a risk level of one-in-one million is a policy decision which needs to be discussed in the broader context of managing environmental health risks.

Response: For carcinogens, the Ministry proposals are within the range of risk levels recommended by the USEPA. The one-in-one million risk level is also used as the 'de minimus' limit in many jurisdictions (i.e. a level below which no action needs to be taken). The discussion paper entitled: "Proposed Risk Management Framework for the Air Standard Setting Process in Ontario" outlines options for those who cannot attain the one-in-one million risk level for any new proposed effects-based air standards.

Comment: Regulatory standards in O. Reg. 346 should not be established on the basis of odour impacts but should be used as screening tools only.

Response: Consistent with the intent of Section 14 of the Environmental Protection Act (i.e., prohibition of causing an adverse effect, including nuisance impacts such as odour) and Section 6 of O. Reg. 346, the Ministry believes that it is reasonable to establish regulatory standards on the basis of odour impacts.

7.0 Considerations in the Development of Air Quality Standards for Chlorine

Chlorine is a corrosive agent and an irritant to the skin, eyes and the respiratory system. Exposure by inhalation at a level above 0.5 ppm (1,500 $\mu g/m^3$) may cause irritation to the throat. Higher levels of exposure may affect the respiratory system causing tracheal and bronchial changes, emphysema, chronic pulmonary edema, and congestion as well as damage to the blood tissues.

The US EPA has not provided a health risk assessment for chlorine for exposures through inhalation. Five U.S. states have derived their respective air quality criteria from the occupational exposure limit of 0.5 ppm (1,500 $\mu g/m^3$), from the ACGIH or the NIOSH. These limits were established for the protection of workers from the irritating effects of chlorine. The State of California has established a chronic REL of 7.1 $\mu g/m^3$, which is based on the adverse health effects of chlorine. The OEHHA of the California EPA has recently proposed a revised chronic inhalation REL of 0.06 $\mu g/m^3$, based on a two-year (lifetime) exposure study for respiratory epithelial damages in rats and mice.

The reported geometric mean of the odour thresholds for chlorine is 232 $\mu g/m^3$ which has been used to derive an odour based AAQC for chlorine.

Levels of chlorine which have been found to be toxic to plants are much higher than those considered appropriate for the protection of human health. Thus, a health-based air quality standard should also provide sufficient protection for vegetation.

8.0 Decision

The Ministry of the Environment has reviewed, and considered air quality guidelines and standards used by leading agencies world-wide. Of the criteria reviewed the Ministry has evaluated and accepted the rationale which supports the current occupational exposure limit of 1,500 $\mu g/m^3$ (0.5 ppm) from the ACGIH. The occupational exposure limit of 1,500 $\mu g/m^3$ is

divided by a factor of 1.5 to convert from an 8-hour TWA to 24-hour average concentration and an uncertainty factor of 100 is applied to obtain a 24-hour AAQC of 10 $\mu g/m^3$.

In summary, based on the information reviewed from leading agencies and the assessment of toxicological information, and the stakeholder comments, the following Ambient Air Quality Criteria are set for chlorine:

- **10 $\mu g/m^3$ (24-hour average) based on health effects; and,**
- **230 $\mu g/m^3$ (10-minute average) based on odour nuisance.**

Based on supporting science and dispersion modelling, a half-hour POI standard of 30 $\mu g/m^3$ can be derived. However, considering the magnitude of the reduction from the previous standard of 300 $\mu g/m^3$ to this revised level of 30 $\mu g/m^3$, meeting this proposed POI standard immediately may not be possible.

In light of these potential concerns, the Ministry has determined an interim POI standard for chlorine:

- **300 $\mu g/m^3$ (half-hour average).**

An interim Point of Impingement (POI) standard of 300 $\mu g/m^3$ (micrograms per cubic metre of air; 30 minute average) has been determined for chlorine from the proposed range of 30 $\mu g/m^3$ to 300 $\mu g/m^3$, pending the outcome of consultation on a risk management framework, the introduction of new air dispersion models in Ontario, and proposed amendments to O. Reg. 346 to incorporate effects-based air standards with appropriate averaging times. The interim POI is already in place.

The Ministry is currently undergoing stakeholder consultation in the discussion paper "A Proposed Risk Management Framework for the Air Standard Setting Process in Ontario". The risk management framework addresses implementation timeframes for adopting final effects-based air standards (POIs and effects-based air standards with appropriate averaging times)as well as technology and economic issues linked to the introduction of new or revised air quality standards and the introduction of new dispersion models into Ontario's regulatory framework. Consultation is also underway in the discussion paper entitled: "Updating Ontario's Air Dispersion Models".

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10.0 Appendix: Agency-Specific Reviews of Air Quality Guidelines

10.1 Agency-Specific Summary: Federal Government of the United States

1. *Name of Chemical*: Chlorine (CAS# 7782-50-5)

2. *Agency*: United States Environmental Protection Agency (US EPA)

3. *Guideline Value(s)*:
For threshold effects, a risk assessment for the chronic inhalation Reference Concentration (RfC) of chlorine is currently under review by the US EPA (1997). The evaluation for chlorine's human carcinogenic potential is under review by an inter-office Agency work group (US EPA, 1997). No air concentration guidelines exist for chlorine.

4. *Application*:
The US EPA has prepared and maintained a database of health risk and regulatory information. This database is called the Integrated Risk Information System (IRIS) and was developed to provide consistent risk information on chemical substances for use in decision-making and regulatory activities. The values reported in IRIS do not represent guidelines or standards.

5. *Documentation Available*:
US EPA, 1997. Integrated Risk Information System (IRIS) Computerised Database. United States Environmental Protection Agency, Washington DC.

6. *Peer-Review Process and Public Consultation*:
The US EPA makes use of peer-reviewed scientific literature, to assess the hazard and to evaluate the potential dose-response relationship of the chemical under review. The assessment methodology and the chemical-specific information undergo scientific and policy reviews.

7. *Status of Guideline*:
Not applicable.

8. *Key Risk Assessment Considerations*:
No information available.

9. *Key Risk Management Considerations*:
No information available.

10. *Multimedia Considerations of Guidelines*:
No information available.

11. *Other Relevant Factors*:
No information available.

10.2 Agency-Specific Summary: State of California

1. *Name of Chemical*: Chlorine (CAS # 7782-50-5)

2. *Agency*: State of California Office of Environmental Health Hazard Assessment (OEHHA); California EPA, Air Resources Board (ARB); California Air Pollution Control Officers Association (CAPCOA)

3. *Guideline Value(s)*:
The State of California does not identify any specific air quality guideline value for chlorine. However, a health-based chronic reference exposure level (REL) of 0.2 $\mu g/m^3$ has been adopted for chlorine. At present, the State of California has also adopted an acute one-hour REL of 23 $\mu g/m^3$ for chlorine. This level is equivalent to the ambient concentration limit (ACL) which is applied in "quantitative risk assessments of non cancer health effects for acute exposure to air pollutants." This REL is currently being revised by the State and a new level for the acute one-hour REL of 210 $\mu g/m^3$ is being proposed and has just been released for public comment.

4. *Application*:
The Revised 1992 Risk Assessment Guidelines were developed by CAPCOA to provide guidance for the risk assessment procedures which are to be used for the Air Toxics "Hot Spots" Program. This program is based on the California State law *Air Toxics "Hot Spots" Information and Assessment Act* detailed under the Health and Safety Code, Section 44360 *et seq.*, 1987. This Act requires local Air Pollution Control Districts to identify facilities in their area which will conduct health risk assessments, outline how such assessments should be prepared and detail how the results are to be used in prioritising substances for needs assessments. These guidelines were prepared to provide a methodology by which consistent risk assessments will be performed, thereby facilitating the comparison and review of such reports. The State does not consider these exposure levels to be legally enforceable air quality guidelines or limit values as they should not be employed outside the scope of the program.

The Toxic Air Contaminant Identification List was compiled by the OEHHA and the ARB as part of the State's Air Toxic Program Assembly Bill (AB)-1807. This draft report presents individual summaries detailing the general exposure and health effects for the 244 substances identified on this list. The summaries are not based upon new California EPA evaluations and do not revise California EPA judgements or polices about the potential for these pollutants to cause harm to human health. Though this document identifies risk-based guidance values which have been established or accepted by the OEHHA, the original documentation for such values should be consulted in order to review the conditions under which these values should be reviewed, interpreted and applied.

The draft document on the Determination of Acute Toxicity Exposure Levels for Airborne Toxicants was released for public comment in 1996 (ARB, 1997). This report provides the supporting documentation rationale for the development of new acute toxicity exposure levels to be applied to various airborne toxicants. It identifies key studies, summarises the human and animal health effects of these toxicants and presents the derivation of revised acute one hour RELs which will be adopted in the future. It must be noted that this is a draft document which is still undergoing public review (OEHHA, 1998).

5. *Documentation Available*:

ARB, 1996. Toxic Air Contaminant Identification List - Summaries (Draft Report). California Environmental Protection Agency - Air Resources Board. Pages 233-235.

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OEHHA, 2000. Determination of Noncancer Chronic Reference Exposure Levels, Chronic Toxicity Summary - Chlorine. Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, California, U.S.A.

6. *Peer-Review Process and Public Consultation*:

The Draft Toxic Air Contaminant Identification List is currently undergoing an extensive peer-review and is open for public review and comments. The sources which were used to compile the technical summaries for the 244 substances identified on the Toxic Air Contaminants Identification List were taken from existing governmental exposure and health effects databases (e.g., Hazardous Substances Database, Integrated Risk Information System, International Agency for Research on Cancer, etc.) and additional widely recognised reference texts.

The reference concentrations (RfCs), RELs, and cancer potency values reported in both the Draft Toxic Air Contaminant Identification List and the CAPCOA documents were prepared and/or adopted for consideration by the OEHHA after extensive review. The rationales for the derivation of all of these values have undergone public review and consultation. Any risk assessment conducted under these guidelines are subjected to review by the local district and the OEHHA. In addition, public input plays a key role in the identification and prioritisation of the areas and facilities for which risk assessments are required. The Determination of Acute

Toxicity Exposure Levels for Airborne Toxicants has been released for public comment, and is currently undergoing public review.

7. *Status of Guideline*:
Not applicable

8. *Key Risk Assessment Considerations*:

Recently, the Office of Environmental Health Hazard Assessments of the California Environmental Protection Agency has revised its chronic inhalation reference exposure level from 7.1 $\mu g/m^3$ to 0.2 $\mu g/m^3$, based on a well-designed animal inhalation study (OEHHA, 2000). This key study involved rats and mice of both sexes, large number of animals (280 per sex per species; 70 per group), a two-year lifetime exposure period, and appropriate selection of endpoints (respiratory epithelial lesions including goblet cell hyperplasia, respiratory epithelium eosinophilic accumulation, glandular epithelium eosinophilic accumulation and olfactory epithelium eosinophilic accumulation.). Mice and male rats were exposed to chlorine concentrations of 0, 0.4, 1 and 2.5 ppm (0, 1.16, 2.9 or 7.25 mg/m^3) for 6 hours/day, 5 days/week. The female rats were exposed to 3 days/week because the authors observed higher sensitivity of the female than the male animals. Statistically significant histological changes in respiratory epithelia were observed in female rats at and above the 0.4 ppm (1.16 mg/m^3) level. Statistically significant responses were observed in the traditional and respiratory epithelial regions of all exposed rats and mice. Similarly significant damages to the olfactory epithelium occurred in all exposed rats and female mice and also in the male mice exposed to 1.0 ppm (2.9 mg/m^3) and 2.5 ppm (7.25 mg/m^3) concentrations. The 0.4 ppm (1.16 mg/m^3) was considered the LOAEL of this study. A benchmark dose (BMC_{05}) of 0.14 ppm has also been established. In order to extrapolate for human exposure, the BMC_{05} of 0.14 ppm (0.41 mg/m^3) was corrected for continuous environmental exposure (for 6 hours/day; 3 days/week) and for extrathoracic respiratory effects (for human equivalent concentration; RGDR=0.16; BW = 229 g; MV = 0.17 L/min; SA(ET) = 15 cm^2). In addition, a total uncertainty factor of 30 was applied, including 3 for inter-species variability and 10 for intra-species variabilities. Finally, a chronic exposure reference level of 0.08 ppb or 0.2 $\mu g/m^3$ was obtained. The benchmark dose (BMC_{05}) analysis performed on data for glandular epithelium eosinophilic accumulation in female rats indicated a 3-fold lower value than the LOAEL of 0.4 ppm (1.16 mg/m^3). A BMC_{05} or BMC_{10} has been considered to be similar to a NOAEL in estimating a concentration associated with a low level risk.

The acute REL of 23 $\mu g/m^3$ was adopted from the ACLs derived by Lewis and Alexeeff (CAPCOA, 1993). This limit is applied as a risk-based short-term one-hour exposure level for chlorine (CAPCOA, 1993). The toxicological endpoint considered in the development of both the chronic and acute REL is respiratory irritation (ARB, 1996). The proposed new acute one-hour REL of 210 $\mu g/m^3$ is derived from an epidemiological study by Anglen (1981) which

examined the effects of chlorine on the respiratory system. This study identified a 30-minute exposure to 2,900 $\mu g/m^3$ to chlorine to be a no-observed-adverse-effects-level (NOAEL). The new REL of 210 $\mu g/m^3$ was then calculated by adjusting this NOAEL with an uncertainty factor of 10 for sensitive individuals, and extrapolating to a one-hour exposure.

However, in the study of Anglen (1981), it was reported that exposure to chlorine at 1 ppm (2,900 $\mu g/m^3$) for 1 hour induced consistent and statistically significant increase in throat irritation and a significant decrease in group mean forced expiratory volume (FEV_1; possible changes in pulmonary function). Exposure to 0.5 ppm (1,500 $\mu g/m^3$) for 4 hours did not consistently induce throat irritation and urge to cough. There is no detail reported by the OEHHA how the exposure time of 30 minutes was determined. As well, the LOAEL would appear to be 1 ppm and the NOAEL be 0.5 ppm. A no-observed-effect level of 0.4 ppm (1,160 $\mu g/m^3$) for an1-hour exposure had been observed for the lack of an effect on changes in FEV_1 in human volunteers with hypersensitive airways (D'Alessandro *et al.*, 1996 as cited in OEHHA, 1998)

Proposition 65 Safe Drinking Water and Toxic Enforcement Act was issued in 1986 by the California Environmental Protection Agency. This Act details the current status of daily intake levels which have been derived or adopted for carcinogens and reproductive toxicants identified by the OEHHA (ARB, 1996). California has not set a daily intake value for chlorine. The State recognises that the US EPA's RfC is currently under review (ARB, 1996). Chlorine is not listed under Proposition 65 as a reproductive or developmental toxicant, nor as a carcinogen (ARB, 1996).

Chlorine is identified on the June 1996 Toxic Air Contaminants Identification List but has yet to undergo a "needs assessment," which is the State's next step in establishing a potential air quality guideline value (ARB, 1997).

9. *Key Risk Management Considerations*:
Not applicable.

10. *Multimedia Considerations of Guidelines*:
The State of California requires risk assessments to consider exposure to certain substances via non-inhalation pathways (specific compounds are listed under Table III-5 in CAPCOA, 1993). Chlorine is not one of these substances.

11. *Other Relevant Factors*:
Chlorine is identified by CAPCOA as a quantifiable and reportable substance in any risk assessment undertaken by a facility posting emissions and/or any risk assessment which is required under the "Hot Spots" Program.

10.3 Agency-Specific Summary: Commonwealth of Massachusetts

1. *Name of Chemical*: Chlorine (CAS# 7782-50-5)

2. *Agency*: Commonwealth of Massachusetts, Department of Environmental Protection (MDEP)

3. *Guideline Value(s)*:
The Threshold Effects Exposure Limit (TEL) is 3.95 $\mu g/m^3$ (24-hour average). The TEL is based on consideration of threshold effects. The Allowable Ambient Limit (AAL) is 3.95 $\mu g/m^3$ (annual average). The AAL is based on consideration of threshold and non-threshold effects.

4. *Application*:
The TEL and AAL are to be employed in the permitting, compliance and enforcement of the Commonwealth of Massachusetts Air Quality Program. The primary goal of the TELs and AALs developed by MDEP is to protect public health from any air contaminant causing known or potentially deleterious effects. These guidelines were developed without regard to production volume, exposure levels, regulatory implications, economic considerations, or control technology issues.

5. *Documentation Available*:
MDEP, 1990. The Chemical Health Effects Assessment Methodology and the Method to Derive Allowable Ambient Air Limits. Vol. I and II. Commonwealth of Massachusetts, Department of Environmental Protection, Boston, Massachusetts. May 1990.

MDEP, 1994. Memorandum from the Office of Research and Standards dated October 20, 1994. This memorandum outlines a number of revisions to the 1990 Chemical Health Effects Assessment Methodology and the Method to Derive Allowable Ambient Air Limits, Commonwealth of Massachusetts, Department of Environmental Protection, Boston, Massachusetts.

MDEP, 1995. Summary Table of Massachusetts Threshold Effects Exposure Limits (TELs) and Allowable Ambient Limits (AALs) for Ambient Air. Massachusetts Department of Environmental Protection (MDEP), Office of Research and Standards, Boston, Massachusetts. December 1995.

Key Reference(s):
ACGIH, 1987. Threshold Limit Values and Biological Indices 1987-1988. American Conference of Governmental Industrial Hygienists Inc., Cincinnati, Ohio.

6. *Peer-Review Process and Public Consultation*:
In the development of the Massachusetts ambient air guidelines, peer-reviewed scientific data and analyses from both public and government sources were used. Toxicological information and exposure limits from the following agencies were reviewed: United States Environmental Protection Agency (US EPA), the International Agency for Research on Cancer (IARC), the American National Toxicology Program (NTP), the National Institute of Occupational Safety and Health (NIOSH), the American Conference of Governmental Industrial Hygienists (ACGIH), and the Occupational Safety and Health Administration (OSHA). Internal and external peer-review and public consultation processes have been carried out since 1982.

7. *Status of Guideline(s)*:
Current. Guidelines may be updated periodically.

8. *Key Risk Assessment Considerations*:
The MDEP has developed a policy for establishing air limits. The methodology addresses both threshold and non-threshold effects, with the selection of the final AAL based on the most sensitive effect. The process focuses primarily on hazard identification and dose-response assessment.

Threshold Effects
Assuming that a chemical has a threshold for adverse effect(s), occupational limits are used to derive the TEL. Where a reference concentration (RfC) exists for a chemical and is published in the Integrated Risk Information System (IRIS) by the US EPA, the methodology outlined in MDEP (1990) has been adapted (MDEP, 1994) to include the RfC in the derivation of TEL and AAL where appropriate and defensible. In the case of chlorine, no IRIS RfC was reported. The MDEP, after having reviewed the ACGIH occupation exposure limit for chlorine, has adopted the level of 0.5 ppm (equivalent to 1.45 mg/m^3, assuming 25°C, 1 atmosphere, and molecular weight of 70.91 g/mol). For use in the MDEP air guidelines this level was considered the Most Appropriate Occupational Limit (MAOL) and adjusted by the following factors:

I. divided by 4.2 to account for continuous exposure. This converts the occupational exposure limit which considers exposure to occur for 8 hours per day, 5 days per week to 24 hours per day, seven days per week.
II. divided by 1.75 to account for differences in sensitivity between adults and children.
III. divided by 10 to account for high-risk groups and other sensitive sub-populations.
IV. divided by 1 to account for relatively complete data in the toxicity database used to review the potential toxicity of chlorine.

The factor applied to the MAOL to calculate the "adjusted" MAOL is 4.2 x 1.75 x 10 = 73.5. The adjusted MAOL is numerically equivalent to 1.45 mg/m^3/73.5 = 0.1973 mg/m^3 = 19.73 $\mu g/m^3$. At this point, another set of uncertainty factors were applied to the adjusted MAOL:

I. divided by 1. This is an uncertainty factor which accounts for documented developmental or reproductive effects that chlorine exhibits (MDEP, 1990) but has been unaccounted for in the health assessment. Since there is little evidence to suggest that chlorine acts as a developmental or reproductive toxicant, the uncertainty factor is defined as 1.

II. divided by 5 to account for exposure through other media sources. This is based on an assumption that ambient air represents only 20% of the total exposure.

The total uncertainty factor applied to adjust the ACGIH occupational exposure limit is 367.5. The TEL for chlorine was therefore calculated as 3.95 $\mu g/m^3$.

Non-Threshold Effects

The MDEP reported that there was insufficient evidence to classify chlorine's carcinogenic or mutagenic potential (MDEP, 1990). The non-threshold effect exposure limit (NTEL) was developed from the adjusted MAOL (19.73 $\mu g/m^3$) using a non-threshold effects uncertainty factor (NTEUF) of 1. No adjustment was made for multimedia considerations. The resulting NTEL for chlorine was calculated as 19.73 $\mu g/m^3$.

Allowable Ambient Limit

The AAL is the lower of the TEL or NTEL. Therefore, the TEL for chlorine of 3.95 $\mu g/m^3$ was adopted as the AAL.

9. *Key Risk Management Considerations*:

The selection of the AAL is based on the most sensitive end-point of an adverse health effect. The goal of the process is the protection of human health. For carcinogens, the AAL derived in the MDEP process corresponds to a maximum allowable excess lifetime cancer risk of one in one million (10^{-6}) or less.

The process of derivation of air guidelines does not include consideration of technological, economic or enforcement issues.

10. *Multimedia Considerations of Guidelines*:

The adjusted MAOL used as the basis of the guideline was divided by 5 to allow for contributions from sources of exposure other than air.

11. *Other Relevant Factors*:

None.

10.4 Agency-Specific Summary: State of Michigan

1. *Name of Chemical*: Chlorine (CAS # 7782-50-5)

2. *Agency*: State of Michigan, Department of Environmental Quality (DEQ)

3. *Guideline Value(s)*:
The 8-hour Initial Threshold Screening Level (ITSL) is 15 $\mu g/m^3$.

4. *Application*:
Screening levels are used for the implementation of Michigan's Air Toxic Rules (Rules 230-232), which apply to any new or modified process for which an application for a permit to install is required, and which emits a toxic air contaminant (State of Michigan, 1995). There are two basic requirements of the Air Toxic Rules as follows:

i) each source must apply the best available control technology for toxics (T-BACT);
ii) after the application of T-BACT, the Predicted Ambient Impact (PAI) of each toxic air contaminant cannot exceed its screening level.

The PAI of each toxic air contaminant is determined using the maximum hourly emission rate for that substance from the facility applying for a permit. The PAI is determined by application of a dispersion model or screening method in accordance with specific regulatory provisions (set out in R336.1240 or R336.1241, or both), by a screening method using a Dilution Matrix included in R336.1230 (Table 22), or by a screening method approved by the regulatory authority.

Screening levels for each toxic air contaminant are developed by the Air Quality Division of the DEQ and are applied across the state. They are used in evaluating the acceptability of emissions from new and modified sources of toxic air pollutants. The intent is to protect ambient air, but the screening levels are not ambient air standards *per se*. Rather, they are health-based levels which the PAI of emissions from a subject facility cannot exceed. If the PAI exceeds the screening level set for a substance, facility-specific physical or operational changes will be required to reduce emissions in order for a permit to be issued.

5. *Documentation Available*:
State of Michigan, 1989. Final Report of the Michigan Air Toxics Policy Committee-A Proposed Strategy for Processing Air Quality Permit Applications for New Emission Sources of Toxic Air Pollutants. Michigan Department of Natural Resources.

State of Michigan, 1992. R336.1230 Air Toxics from new and modified sources.

State of Michigan, 1995. Procedures for Developing Screening Levels. Michigan Department of Natural Resources, Air Quality Division.

State of Michigan, 1997. List of Screening Levels (ITSL, IRSL, and SRSL) for Michigan's Air Toxic Rules. Michigan Department of Environmental Quality, Air Quality Division.

Key Reference(s):
ACGIH, 1991. Documentation of the Threshold Limit Values and Biological Exposure Indices. Sixth Edition. American Conference of Governmental Industrial Hygienists Inc., Cincinnati, Ohio.

6. *Peer-Review Process and Public Consultation*:
Peer-reviewed scientific research data, analyses and evaluations from various sources were employed in the development of this value. Specifically, the American Conference of Governmental Industrial Hygienists' (ACGIH) process for development of Threshold Limit Values (TLVs), upon which the ITSL for chlorine is based, were employed.

7. *Status of Guideline*:
Current.

8. *Key Risk Assessment Considerations*:
The health assessment methodology used by the DEQ for non-carcinogenic compounds involves determination of an ITSL. The ITSL is a regulatory level used in evaluating the acceptability of emissions from new and modified sources of toxic air pollutants. The ITSL is set at some fraction of the observable threshold dose determined in studies using laboratory animals or from humans. The methodology for determining the ITSL is contained in Rule 232.

The ITSL for chlorine was determined from the Threshold Limit Value-Time-Weighted-Average (TLV-TWA) established by the ACGIH and has an averaging time of 8 hours. The ITSL was determined by dividing the occupational exposure level (OEL) (in this case, the TLV-TWA from ACGIH) by 100. The 100 fold safety factor is derived as follows:

$$\text{ITSL} = \text{OEL} \times A \times B \times C$$

$$= \text{OEL} \times \frac{40 \text{ hours}}{168 \text{ hours}} (A) \times \frac{30 \text{ years}}{70 \text{ years}} (B) \times \frac{1}{10} (C) = \frac{\text{OEL}}{100}$$

where:

A adjusts for the difference between a 40 hour work week and the total hours in a week;
B adjusts for the difference between the number of years a person is assumed to work and the total estimated lifetime;
C adjusts for the possible higher susceptibility of certain individuals in the general population when compared to the healthy adult worker.

The ACGIH established a TLV-TWA of 0.5 ppm for chlorine (ACGIH, 1991). TLV-TWAs refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effects.

With a conversion factor of 1 ppm = 2.9 mg/m^3, 0.5 ppm is equivalent to 1.45 mg/m^3 or 1,450 $\mu g/m^3$. This was divided by 100 and rounded up to arrive at the ITSL of 15 $\mu g/m^3$.

9. *Key Risk Management Considerations*:
None.

10. *Multimedia Considerations of Guidelines*:
None.

11. *Other Relevant Factors*:
None.

10.5 Agency-Specific Summary: State of New Jersey

1. *Name of Chemical*: Chlorine (CAS # 7782-50-5)

2. *Agency*: Department of Environmental Protection (NJDEP) - State of New Jersey

3. *Guideline Value(s)*:
The State of New Jersey has not identified a specific air concentration guideline value for chlorine. The New Jersey Bureau of Air Quality Evaluation (BAQEv) bases its guideline values on the information made available from the US EPA and other sources. A reference concentration (RfC) of 7.1$\mu g/m^3$, based on the reference exposure level outlined under the State of California's Committee of the California Air Pollution Control Officers Association (CAPCOA) 1993 Risk Assessment Guidelines has been adopted by the NJDEP (NJDEP, 1997).

4. *Application*:
The BAQEv Air Quality Permitting Program (AQPP) requires risks to be assessed in conjunction with applying for an air pollution control pre-construction permit. Risks are assessed either by a risk screening conducted by AQPP staff or by a refined risk assessment completed by the applicant. The approach chosen is based on the type and size of the facility or source. The risk assessment must address any toxic air contaminant declared under the New Jersey Administrative Code Toxic Substances List (7:27-17) or which are listed on the Federal Hazardous Air Pollutants List posted under the *Clean Air Act* (NJDEP, 1994).

5. *Documentation Available*:
NJDEP, 1997. Memorandum regarding the revision of Reference Concentration List. Department of Environmental Protection.

NJDEP, 1994. Technical Manual 1003 - Air Quality Regulation Program Bureau of Air Quality Evaluation: Guidance on Preparing Risk Assessment for Air Contaminant Emissions. New Jersey Department of Environmental Protection, Air Quality Permitting Program, Bureau of Air Quality Evaluation.

Key Reference(s):
CAPCOA, 1993. Air Toxics "Hot Spots" Program. Revised 1992 Risk Assessment Guidelines. Toxics Committee of the California Air Pollution Control Officers Association.

6. *Peer-Review Process and Public Consultation*:
None.

7. *Status of Guideline*:
Not applicable.

8. *Key Risk Assessment Considerations*:
The State adopted the State of California's chronic REL of 7.1 $\mu g/m^3$ (NJDEP, 1997). This risk-based reference level is based on the ACGIH TLV-Time-Weighted-Average (TLV-TWA) for chlorine. The derivation of this level is detailed in section 5.2 State of California.

9. *Key Risk Management Considerations*:
Not applicable.

10. *Multimedia Considerations of Guidelines*:
The risk screening procedure used by the AQPP considers only inhalation exposure. Refined risk assessments conducted by permit applicants consider all likely exposure pathways. Unit risk factors (URFs) must be used to calculate inhalation risks for carcinogens, while potency factors are used to calculate risks from oral and dermal exposures. For non-carcinogens, RfCs must be used for inhalation exposure, and reference doses (RfDs) are used for oral and dermal exposures. The calculated doses from each route of exposure are summed to yield the total dose.

11. *Other Relevant Factors*:
None.

10.6 Agency-Specific Summary: New York State.

1. *Name of Chemical*: Chlorine (CAS#7782-50-5)

2. *Agency*: New York State Department of Environmental Conservation (NYSDEC), Division of Air Resources

3. *Guideline Value(s)*:
Short-term Guideline Concentration (SGC) for chlorine is 350 $\mu g/m^3$ (1-hour average). Annual Guideline Concentration (AGC) for chlorine is 3.5 $\mu g/m^3$.

4. *Application*:
The NYSDEC guidelines for the control of toxic ambient air contaminants is intended primarily for use in the decision-making process of permitting emissions (6NYCRR Parts 200, 201, 212 and 257), and for application of certificates of operation for sources of air contamination. The regulatory process used in NYSDEC provides both short- and long-term guidelines to establish appropriate control requirements under existing statutes. The guidelines have been developed to aid the regulatory decision making process using scientific data and professional judgement. However, they have not been subjected to the same degree of review as applied to an environmental standard.

5. *Documentation Available*:
NYSDEC, 1991. New York State Air Guide-1. Guidelines for the Control of Toxic Ambient Air Contaminants. Daft. New York State Department of Environmental Conservation, Division of Air Resources. Albany, New York.

Key Reference(s):
NIOSH, 1988. NIOSH Recommendations for Occupational Safety and Health Standards. U.S. Department of Health and Human Services. Public Health Service. National Institute of Occupational Safety and Health (NIOSH), Centers for Disease Control, Atlanta, Georgia. Morbidity and Mortality Weekly Report. Vol. 37. No. S-7. August 26, 1988.

6. *Peer-Review Process and Public Consultation*:
Peer-reviewed data and computer models were used in the development of the scientific documents supporting the air guidelines. Scientific and professional judgment were employed in the toxicological assessment of contaminant classification and in the screening model analysis.

There are opportunities for public consultation, including the option to review the guidance used in the development of guidelines under certain circumstances and/or the option to develop an ambient air guideline for a contaminant not listed in the current guidelines.

7. *Status of Guideline(s)*:
Current.

8. *Key Risk Assessment Considerations*:
Chlorine is classified as a moderate toxicity air contaminant (Table III, Appendix C of NYSDEC, 1991). Moderate toxicity air contaminants are defined as animal oncogens, developmental and reproductive toxicants, genotoxic chemicals and other chemicals posing a health hazard to humans.

The SGC was derived from the NIOSH Recommended Exposure Limit-Time Weighted Average (REL-TWA) of 1.5 mg/m^3 (1988) by dividing the NIOSH REL-TWA by 4.2 and rounding down to 350 $\mu g/m^3$. The AGC was derived from NIOSH REL-TWA (1988) by dividing the NIOSH REL-TWA by 420 and rounding down to 3.5 $\mu g/m^3$.

$$SGC = 1.5\ mg/m^3 / 4.2 = 0.357\ mg/m^3 \approx 350\ \mu g/m^3$$
$$AGC = 1.5\ mg/m^3 / 420 = 0.00357\ mg/m^3 \approx 3.5\ \mu g/m^3$$

The factor used above as the divisor to adjust the occupational limit is based on adjusting 8 hour/day, 5 days/week occupational exposure to 24 hours/day, 7 days/week environmental exposure (i.e., factor of 4.2). To compensate for applying occupational guidelines to the general population in establishing an AGC, an additional factor of 10 is used for contaminants defined as low toxicity chemicals and a factor of 100 is used for contaminants defined as moderate toxicity chemicals.

9. *Key Risk Management Considerations*:
Specific computer models have been identified by the agency for use in impact screening as required in the permitting process.

10. *Multimedia Considerations of Guidelines*:
The NYSDEC guideline considers only human exposure to contaminants in the air.

11. *Other Relevant Factors*:
None.

10.7 Agency-Specific Summary: World Health Organization (WHO)

1. *Name of Chemical*: Chlorine (CAS # 7782-50-5)

2. *Agency*: World Health Organization

3. *Guideline Value(s)*:
None.

4. *Application*:
None.

5. *Documentation Available*:
WHO, 1987. Air Quality Guidelines for Europe. WHO Regional Publications, European Series No. 23. World Health Organization, Regional Office for Europe, Copenhagen, Denmark.

6. *Peer-Review Process and Public Consultation*:
Not applicable.

7. *Status of Guideline*:
Not applicable.

8. *Key Risk Assessment Considerations*:
None.

9. *Key Risk Management Considerations*:
None.

10. *Multimedia Considerations of Guidelines*:
None.

11. *Other Relevant Factors:*
None.

10.8 Agency-Specific Summary: The Netherlands

1. *Name of Chemical*: Chlorine (CAS # 7782-50-5)

2. *Agency*: Netherlands Ministry of Housing, Spatial Planning and the Environment

3. *Guideline Value(s)*:
Chlorine is classified as a class 2 gaseous inorganic substance (gA.2). This classification imposes an emission standard of 5,000 $\mu g/m^3$ given a mass flow rate of 0.05 kg/hr or more. This standard is applied as a half-hourly average upper emission limit. (Netherlands Emission Regulations Staff Office, 1992).

4. *Application*:
These emission regulations are intended for use by all licensing authorities in the Netherlands in order to standardise the rules by which emissions are regulated in conjunction with licensing. These emission standards are to be applied as the maximum permissible emission concentration for different waste gas components on a facility specific basis. They are applied to emissions occurring at each source and at the point from which the waste gases leave the processing unit.

Compounds have been categorised into substance classes based on their respective toxicological profiles. There are four substance categories into which compounds are divided (carcinogens, particulates (general), organic or inorganic particulates, and organic or inorganic matter in gaseous or vaporous forms). The emission standard is based on a mass flow limit which has been established for each substance class derived from the application of best available technology. When the untreated mass flow rate of a substance or a class of substances exceeds the critical mass flow limit established for that class, the standard in question is applied to the total discharge for all sources emitting the compound or compounds in that class. Untreated mass flow is defined as "the mass of a particular single substance or summed masses of substances in the same class emitted per unit of time and before any treatment by means of add-on technology" (Netherlands Emission Regulations Staff Office, 1992).

5. *Documentation Available*:
Netherlands Emission Regulations Staff Office, 1992. Netherlands Emission Regulations - Air (NeR). Netherlands Emission Regulations Staff Office. Bilthoven, The Netherlands.

Netherlands Ministry of Housing, Spatial Planning and the Environment, 1994. Environmental Quality Objectives in the Netherlands - A review of environmental quality objectives and their policy framework in the Netherlands. Risk Assessment and Environmental Quality Division, Ministry of Housing, Spatial Planning and the Environment. The Hague, The Netherlands.

6. *Peer-Review Process and Public Consultation*:
The Netherlands Emission Regulations and the Environmental Quality Objectives documents were not peer-reviewed or released for public comment.

7. *Status of Guideline*:
Current.

8. *Key Risk Assessment Considerations*:
The mass flow limits for the substance classes are based on the German TA-luft Program (Directorate-General for Environmental Protection, 1997). When the untreated mass flow per class exceeds the critical mass flow limit established for that class, the standard in question is applied to the total discharge for all sources emitting compounds in that class. The standard serves as an average half-hourly upper emission limit of 5,000 $\mu g/m^3$ in the case of a mass flow of 0.05 kg/hr or more upon the application of best available technology. Mass flow is defined as "the mass of a particular substance or group of substances from the same class emitted per unit of time" (Netherlands Emission Regulations Staff Office, 1992).

9. *Key Risk Management Considerations*:
These Netherlands Emission Regulations standards do not replace existent binding emission or national air quality legal regulations and/or standards. These standards are only to be used as a guidance for licensing agencies until the Dutch Emission Guidelines for the granting of licences is released under the *Environmental Protection Act*.

10. *Multimedia Considerations of Guidelines*:
None.

11. *Other Relevant Factors*:
None.

10.9 Agency-Specific Summary: Swedish Institute of Environmental Medicine

1. *Name of Chemical*: Chlorine (CAS# 7782-50-5)

2. *Agency*: Swedish Institute of Environmental Medicine

3. *Guideline Value(s)*:
No guideline available.

4. *Application*:
The air emissions in Sweden are regulated by one of two authorities: i) the regional County Government Boards; or ii) the central authority, called the National Licensing Board for Environmental Protection. The basis for the guidelines is permitting of emissions from industrial, heat and power plants.

5. *Documentation Available*:
Victorin, K., 1993. Health effects of urban air pollutants. Guideline values and conditions in Sweden. Chemosphere 27(9) 1691-1706.

Key Reference(s):
None available.

6. *Peer-Review Process and Public Consultation*:
No Information available.

7. *Status of Guideline*:
Not applicable.

8. *Key Risk Assessment Considerations*:
The Institute of Environmental Medicine has performed a number of health risk evaluations on chemicals found in combustion emissions. In general, the Institute develops air guideline values by taking the lowest-observed-effect-level in humans for that compound and applying a factor of between 100 and 1,000. For cancer-causing chemicals, air guidelines may be based on a lifetime cancer risk of 1×10^{-5}.

9. *Key Risk Management Considerations*:
No information available.

10. *Multimedia Considerations of Guidelines*:
No information available.

11. *Other Relevant Factors*:
None.

10.10 Agency-Specific Summary: Federal Government of Canada (CEPA)

1. *Name of Chemical*: Chlorine (CAS # 7782-50-5)

2. *Agency*: Environment Canada/Health Canada - *Canadian Environmental Protection Act*

3. *Guideline Value(s)*:
No guideline has been established. Chlorine has not been assessed or evaluated under the first Priority Substance List (PSL1). It was nominated as a substance for consideration, but was not recommended for evaluation by the Ministers' Expert Advisory Panel under the Second Priority Substance List (PSL2).

Application:
The *Canadian Environmental Protection Act* (CEPA) requires the federal Ministers of the Environment and Health to prepare and publish a Priority Substances List (PSL) that identifies substances that may be harmful to the environment or constitute a danger to human health. The Act also requires both Ministers to assess these substances and determine whether they are "toxic" as defined in Section 11 of the Act. The assessment of whether substances are toxic is based on the determination of whether they enter or are likely to enter the Canadian environment in an amount that could lead to exposure of humans or other biota at levels that could cause adverse effects.

Substances that are assessed as "toxic" may be placed on Schedule I of the Act and considered for possible development of regulations or guidelines.

5. *Documentation Available*:
Environment Canada, PSL2 Secretariat, 1995. Report of the Ministers' Expert Advisory Panel on the Second Priority Substances List Under the *Canadian Environmental Protection Act* (CEPA). October, 1995.

6. *Peer-Review Process and Public Consultation*:
CEPA underwent comprehensive public consultation and review. PSL documents are based on peer-reviewed literature and are peer-reviewed prior to being released.

7. Status *of Guideline*:
Not applicable.

8. *Key Risk Assessment Considerations*:
Not applicable.

9. *Key Risk Management Considerations*:
Not applicable.

10. *Multimedia Considerations of Guidelines*:
Not applicable.

11. *Other Relevant Factors*:
Not applicable.

11.0 Acronyms, Abbreviations and Definitions

AAL	*Allowable Ambient Level* (Massachusetts)
AAQC	*Ambient Air Quality Criteria* - used by the Ontario Ministry of the Environment to define the potential for causing an adverse effect
ACGIH	*American Conference of Governmental Industrial Hygienists* - a non-governmental organization which establishes occupational safety exposure limits for workers
AGC	*Annual guideline Concentration* (New York State)
ATSDR	*Agency for Toxic Substances and Disease Registry* - an agency of the US Department of Health & Human Services
CAPCOA	*California Air Pollution Control Officers Association*
CAS	*Chemical Abstracts Service* - ascribes a unique, identification (registry) number to each chemical to help clarify multiple listings for the same chemical structure
CEPA	*Canadian Environmental Protection Act*
GLC	*Ground Level Concentration* - the concentration of contaminant predicted by dispersion modelling
HEAST	*Health Effects Assessment Summary Tables* - prepared by US EPA's Office of Health and Environmental Assessment. HEAST contains risk assessment information on chemicals that have undergone reviews, although generally not as extensive as the reviews conduced under IRIS
HEC	*Human Equivalent Concentration*
IARC	*International Agency for Research on Cancer*
IRIS	*Integrated Risk Information System* - a database published by the US EPA containing risk assessment information on a wide range of chemicals
IRSL	*Initial Risk Screening Level* - a limit corresponding to a one in a million lifetime risk of cancer used by Michigan for screening new sources of emissions
ITSL	*Interim Threshold Screening Level* - similar to the IRSL, however, derived from the RfC for non-carcinogens
LC_{50}	The concentration of a substance in the medium (eg., air, water, soil) to which a test species is exposed, that will kill 50% of the population of that given species
LD_{50}	The dose of a substance given to a test species, that will kill 50% of the population of that given species
LOAEL	*Lowest-Observed-Adverse-Effect Level*
LOEL	*Lowest-Observed-Effect Level*
MAC	*Maximum Acceptable Concentration*
MACT	*Maximum Achievable Control Technology*
µg	a microgram, one millionth of a gram
mg	a milligram, one thousandth of a gram
MRL	*Minimal Risk Level* - a term used by ATSDR, which defines a daily exposure [either from an inhalation or oral route] not likely to induce adverse

	non-carcinogenic effects within a given time period, ie., acute, intermediate, or chronic
MOE	*Ontario Ministry of the Environment*; between 1993 and 1997 known as **MOEE** or Ontario Ministry of Environment and Energy
ng	a nanogram, one billionth of a gram
NIEHS	*National Institute of Environmental Health Sciences* (USA)
NIOSH	*National Institute for Occupational Safety and Health* (an agency of the US Department of Health & Human Services)
NOAEL	*No-Observed-Adverse-Effect Level*
NOEL	*No-Observed-Effect Level*
NPRI	*National Pollutant Release Inventory*
NTP	*National Toxicology Program* (USA)
OEHHA	*Office of Environmental Health Hazard Assessment* (California EPA)
OEL	*Occupational Exposure Level*
OSHA	*Occupational Safety and Health Administration* - a branch of the US Dept of Labour
PEL	*Permissible Exposure Limit* (OSHA air standard)
POI	*Point of Impingement* - used in conjunction with dispersion modelling to define the area in which the maximum ground level concentration (GLC) of a contaminant is predicted to occur
ppb	parts per billion
ppm	parts per million
REL	**Either** '*Reference Exposure Level*' as used by the California EPA which defines the concentration at or below which no adverse health effects are expected in the general population **or** '*Recommended Exposure Limit*' used by both NIOSH and ATSDR
RfC	*Reference Concentration* - an estimate of a daily inhalation exposure not likely to induce deleterious non-cancer health effects during a lifetime
RfD	*Reference Dose* - an estimate of a daily exposure dose not likely to induce adverse health effects during a lifetime
RTECS	*Registry of Toxic Effects of Chemical Substances* - database maintained by NIOSH
SGC	*Short-term Guideline Concentration* (New York State)
STEL	*Short-term Exposure Limit*
TC	*Tolerable Concentration* - used by Health Canada to define the airborne concentration to which a person can be exposed for a lifetime without deleterious effects (for non-carcinogens)
TC_{05}	*Tumorigenic concentration* - the concentration of a contaminant in air generally associated with a 5% increase in incidence or mortality due to tumours
TD_{05}	*Tumorigenic dose* - the total intake of a contaminant generally associated with a 5% increase in incidence or mortality due to tumours

TLV	*Threshold Limit Value* - an exposure concentration that should not induce an adverse effect in a work environment
TWA	*Time-Weighted-Average* - allowable exposure averaged over an 8-hour workday or 40-hour work week
US EPA	*United States Environmental Protection Agency*
WHO	*World Health Organization*